HOSTED BY

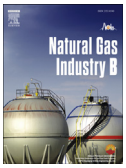
ELSEVIER

Available online at www.sciencedirect.com

ScienceDirect

Natural Gas Industry B 1 (2014) 103–112

www.elsevier.com/locate/ngib



Research article

Natural gas supply-demand situation and prospect in China

Zhang Kang

Sinopec Petroleum Exploration and Development Research Institute, Beijing 100083, China

Received 31 October 2013; accepted 25 January 2014
Available online 1 November 2014

Abstract

Since the 21st century, the reserves of conventional natural gas as well as tight gas in China have been decreasing and their annual production growth rates have been generally reduced from double-digit to one-digit number of percentage. It is predicted that natural gas production will possibly reach up to 134 billion m^3 in 2015; and if the marketable rate is 90%, the gas supply volume will probably be 120.6 billion m^3 in 2015. Since shale gas development just has started currently, about 0.6 billion m^3 of the marketable shale gas will be added to gas supply in 2015. The CBM gas production especially such gas consumption has long been lagged behind the expected targets, and what's more, flaws exist in their statistics; on this basis, it is assumed that the marketable CBM gas will be 4 billion Nm^3 in 2015. With so many achievements made in the coal gas exploitation, it is forecasted that about 5.5 billion m^3 coal gas will be added to gas supply in 2015. In total, the domestic fuel gas supply is roughly estimated to be 131 billion m^3 in 2015; if the gas consumption in the year is presumably 231 billion m^3, about 100 billion m^3 gas will then be imported in 2015. From the presumable actual imports of piped gas and LNG terminals, there is still a gap of 27–30 billion m^3 in 2015. Therefore, it is suggested that more LNG receiving terminals be put into production in advance and the increment of import gas be needed from Middle Asia. Also, it is proposed that the statistics be completed on the practical marketable fuel gas quantity in the fundamental study of energy planning in the National 13th Five-Year Plan. In conclusion, the economic system reform process is the key to the further development of oil and gas industry in China.

Keywords: China; Natural gas; Reserves; Production; Growth rate; Supply-demand situation; Marketable gas; Conventional natural gas; Unconventional natural gas; Imported natural gas

On the half way of the "12th Five-Year Plan" of China's national economic development, it is urgent to investigate the status of its implementation, get an idea of whether the corresponding targets can be reached on time, and make a plan on the research of the "13th Five-Year Plan" as soon as possible. To this end, we have analyzed the recent supply and demand situation of natural gas and fuel gas in China, and made a framework prediction on the targets that can be reached by the end of the "12th Five-Year Plan", and made suggestions on the basic research of the "13th Five-Year Plan" for reference.

When studying the quantitative indicator system of China's natural gas, the following features of the system are worth noting, which is the prerequisite for conducting in-depth discussion. (1) China's reported natural gas production includes both conventional gas and tight (sandstone) gas (unconventional gas). Gas production in China has been gradually pushing toward tight sandstone reservoirs with poor physical properties that require fracturing and horizontal wells to reach economic development, but since there is no clear or unified definition for tight gas, and systematic statistics on its reserves and production, its reserves and production are included in the conventional gas in report. (2) Current coal bed methane (CBM) reserves and production management are not yet in place, and the statistics from multiple sources differ widely from one another. (3) For lack of serious statistics on marketable gas, many people take the wellhead production as the market supply, which often results in an artificial gap between the supply and sale. This gap is particularly significant in CBM due to its low marketability rate [1]. (4) The fuel gas supply in China does not include coal gas (including coke oven gas), bio-gas, and other synthetic gases. But these types

E-mail address: zhangkang@pepris.com (Zhang K).
Peer review under responsibility of Sichuan Petroleum Administration.

http://dx.doi.org/10.1016/j.ngib.2014.10.014

of gas supply can no longer be ignored because they will be produced on a large scale in the future. As these types of gas get into the supply list, our study objects will also expand from natural gas into fuel gas (often called gaseous fuel abroad), which is more complex in composition.

1. Changes in China's natural gas production in recent period

1.1. Natural gas reserves

China's modern natural gas industry evolved later than China's modern petroleum industry. During the last two decades of the 20th century, it was still in the adolescent stage of fast development. The annual growth rate of Original Gas In-Place (OGIP) reached a two-digit percentage, and was approximately 17.3% during the 1990's [2].

As the base increased and there were fewer new discoveries made, however, the annual growth rate dropped to single digits at the beginning of the 21st century, slowing to 9.47% from 2001 to 2005, 8.0% from 2005 to 2010, then finally to 7.99% and 9.53% in 2011 and 2012, respectively.

What is the most noteworthy is the change in recoverable reserves. Of the newly discovered and proved natural gas reserves, the share of tight sand gas has progressively increased, while the quality of reserves has decreased. Moreover, as production has increased year after year, the annual growth rate of residual recoverable gas reserves (which are the reserves referred to in international general statistics) has decreased as a whole. Therefore, the trend of decreasing residual recoverable gas reserves became evident at the beginning of the 21st century (note that the annual growth rates of residual recoverable reserves in 2011 and 2012 were 1.37% and 2.33% lower than the annual growth rates of OGIP, respectively (Table 1). On the basis of the above points, the author predicts that the annual growth rate of OGIP and the residual recoverable gas reserves in China in 2014 and 2015 will be 8% and 7%, respectively. It is further predicted that the cumulative proved OGIP and residual recoverable gas reserves in China in 2015 will reach 13.616×10^{12} m^3 and 3.817×10^{12} m^3, respectively (i.e. the increases during the "12th Five-Year Plan" period will be approximately 4.48×10^{12} m^3 and 1.09×10^{12} m^3, respectively). Regarding the amount of newly proved OGIP, it is possible that the goal (3.5×10^{12} m^3) set in the "12th Five-Year Plan" will be surpassed.

Table 1
Change of natural gas reserves in China from 2005 to 2015.

	2005 Reserves/10^8 m^3	2010 Reserves/10^8 m^3	Annual growth rate in this period	2011 Reserves/10^8 m^3	Annual growth rate in this period	2012 Reserves/10^8 m^3	Annual growth rate in this period	2015 Reserves/10^8 m^3	Annual growth rate in this period
OGIP	62,176	91,385	8.00%	98,684	7.99%	108,088	9.53%	136,160	8.00%
Residual recoverable gas reserves	28,185	27,257	−0.67%	29,061	6.62%	32,154	7.20%	38,165	7.00%

Notes: All raw data comes from the "National Oil and Gas Mineral Reserves Bulletin". Only data for 2015 were predicted based on annual growth rates of 8% and 7%. (Tabulated and calculated by the author.)

1.2. Conventional gas and tight gas production

The change in China's natural gas production has clearly been periodical (Fig. 1). Production exceeded 200×10^8 m^3 in 1996 and reached 350×10^8 m^3 in 2003, showing an annual growth rate of 7.23%−12.73% and an average annual growth rate of 8.71%. Production exceeded 400×10^8 m^3 in 2004 and 800×10^8 m^3 in 2008, while this period was marked by a high annual growth rate (15.97%−18.96%, at an average of 18.07%). The annual growth rate has decreased significantly

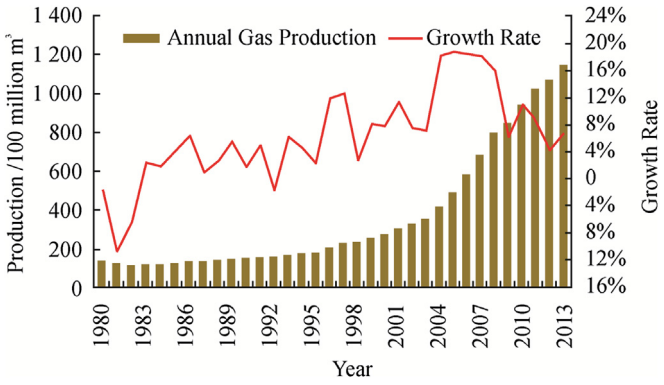


Fig. 1. Change of natural gas production and annual growth rate in China from 1980 to 2013. Notes: According to CNPC Research Institute of Economics and Technology, 2013.

since 2008, although natural gas production has kept increasing (and exceeded 1000 × 10^8 m^3 in 2011). The growth rate (with the exception of 2010 when it reached 11.23%) has apparently been lower than 10% every year, only reaching an average annual growth rate of 7.37% — which was actually 1.34% lower than the average level from 1995 to 2003. After 2005, the annual growth rate of natural gas production has been exhibiting an overall trend of slowdown. Obviously, such significant sustained decrease in the annual growth rate is related to the increasing ratio of tight gas production within its composition. The average annual growth rate from 2010 to 2012 was 6.07%. It was originally predicted in the beginning of 2013 that the natural gas production in that year would be 1150 × 10^8 m^3 and the corresponding annual growth rate would be 7.77%. Based on the above figures, the author predicts that (assuming an annual growth rate of 8%) the total production of conventional gas and tight gas in China in 2015 and 2020 will most likely reach 1340 × 10^8 m^3 and 1970 × 10^8 m^3, respectively (Table 2). Assuming that production actually reaches 1340 × 10^8 m^3 in 2015, the annual growth rate of natural gas production during the "12th Five-Year Plan" period will be 7.16%.

It is believed, based on the trend of change in natural gas reserves and production, that China's natural gas development is already showing the signs of moving from adolescence to maturity [3] and its growth rate is thus slowing down.

Traditionally, there has been a lack of authoritative statistical data regarding natural gas commodity rates in China. According to an unverified internal data, the commodity rate in 2012 was 85.4%. During recent years, the average commodity rate of natural gas worldwide has been 85%. Assuming it will obtain a higher level of approximately 90% in 2015, the commercial production of both conventional gas and tight gas in China should reach 1206 × 10^8 m^3 at that time.

1.3. Shale gas, coalbed gas and coal-made gas

1.3.1. Shale gas

The success of the USA's shale gas revolution has had strong repercussions in China, where the first nationwide shale gas resources evaluation has now been conducted and multiple symposiums have been held. However, these have not truly created a "shale gas fever", because the physical workload invested is still fairly limited and the number of horizontal wells where fracturing production tests are actually attempted has been even more limited. In March 2012, China published the "Shale Gas Development Plan (2011–2015)" (hereinafter referred to as "The Plan"). The Plan has emphasized the need to "lay a robust foundation for promoting rapid development of shale gas during the '13th Five-Year Plan' period" by conducting surveys and evaluations of potential resources, carrying out problem-tackling research on key exploration and development technologies and equipment, and establishing a system of technical standards and industrial policies. The Plan also requires "establishing a number of shale gas exploration and development areas to accomplish preliminary mass production" — while setting the goals of achieving 6000 × 10^8 $m^3$of proved shale gas initially in place, recoverable reserves of 2000 × 10^8 m^3 and production of 65 × 10^8 m^3 in 2015. During recent years, China has taken concrete steps forward in its shale gas efforts, which include studying dark shale of different types (coal measures of marine facies, continental facies, and continental–oceanic interaction facies) and different time periods (Lower Paleozoic Erathem, Upper Paleozoic Erathem, Mesozoic Erathem, and Cenozoic Erathem) and completing fracturing production tests in a number of exploration wells and horizontal wells nationwide (these concrete steps have all been undertaken within a short period of time) [4]. It is especially worth noting that China, having learned from the United States' lesson of "passively" advancing from shale gas to shale oil because of a significant drop of gas prices, has undertaken a strategy of focusing on both shale oil and shale gas from the very beginning [5]. However, as far as the current situation is concerned, until 2015 it will only be possible to implement production tests in a

Table 2
Change of natural gas production in China from 2010 to 2020.

2010 production/10^8 m^3	2012 production/10^8 m^3	Annual growth rate in this period	2013 production/10^8 m^3	Annual growth rate in this period	2015 production/10^8 m^3	Annual growth rate in this period	2020 production/ 10^8 m^3	Annual growth rate in this period
948.5	1067.1	6.07%	1150	7.77%	1340	8.00%	1970	8.00%

Notes: Raw data for 2010 and 2012 from the National Bureau of Statistics; production in 2013 is based on the predictions by the CNPC Research Institute of Economics and Technology; production in 2015 and 2020 was predicted by the author. Natural gas production in this table includes both conventional gas and tight gas. (See the body of this article for details.)

few pilot test well clusters-given that mass production based on block "factory-like" development well patterns would be impossible given the very limited investment and extremely low workload. In light of the present dynamic estimations, it will only be possible to produce about 2×10^8 m^3 of shale gas in 2013, while commercial gas contributions of 6×10^8 m^3 will be possible by 2015. Many of the related researchers believe that the production goal of 65×10^8 m^3 described in the current "Shale Gas Development Plan" is likely to be achieved sometime around 2020.

The requirements for determining proved reserves of unconventional gas, especially shale gas, are different from the requirements for determining proved reserves of conventional gas. Not only is effective control of fairly dense drilling required, but also a set of reliable data generated from single-well production tests (with production test duration typically ranging from one to two years). Obviously, meeting the goal of the proved shale gas reserves mentioned in the above "Plan" is impossible. It would be ideal if shale gas reserves in several blocks could be determined by trial- and-error methodology in order to revise a more feasible draft of shale gas reserve specifications.

1.3.2. Coalbed gas

The problems were identified at the very beginning of this paper that the current coalbed gas administration in China is not standardized as well as that the reserves/production figures given by different organizations are significantly different. According to the current regulations, coalbed gas is treated in the same way as conventional oil and gas, i.e. its exploration and development blocks fall within the scope of national class-A registration and administration [6] and all reserves and production must be approved by the National Reserves Administration Committee, which means related reserves and production balance sheets should be announced on an annual basis. Relevant data regarding coalbed gas are listed in the "National Oil and Gas Mineral Reserves Bulletin". For example, the 2012 Bulletin provided the following data regarding coalbed gas: cumulative proved OGIP of 5430×10^8 m^3, residual recoverable gas reserves of 2191×10^8 m^3, and current-year production of 10.53×10^8 m^3. Furthermore, the summary of production disclosed by individual companies indicates that coalbed gas production nationwide in 2012 was 125×10^8 m^3, which includes 25.7×10^8 m^3 produced via surface extraction. According to the responses by the National Energy Administration during an interview at www.gov.cn on 23 September 2013, production via surface extraction in 2012 was 27×10^8 m^3 (including 20×10^8 m^3actually being used); production via coalmine exhausting was 114×10^8 m^3 (including 38×10^8 m^3actually being used). It is evidenced by comparing the above three sets of data that: (1) what is actually listed in the National Reserves Administration Committee's approved reserves (and for which an annual production is recorded) are only the partial exploration and development outcomes of various individual companies, which indicates that management lags behind the realities of the situation and is not standardized; (2) the quantities of production and utilization reported by different authorities are significantly different.

Even if calculations are carried out based on the production reported by various individual companies, China's coalbed gas production has yet failed, over a prolonged period of time, to meet the requirements of the individual Five-Year Plans of recent decades. In particular, two key indicators, i.e. surface drilling extracted production and the utilization rate of mine exhaust gas, are far from satisfactory. Notably, the growth of coalbed gas reserves during the period of the "11th Five-Year Plan" only reached 60% of the stated goals. As for coalbed gas indexes in 2010, production should have been 100×10^8 m^3 (surface extraction and mine exhaust to account for half each) and the utilization rate should have been 80%. But statistics show that production was merely 86×10^8 m^3 (with surface extraction accounting for only 15.7×10^8 m^3) and the utilization rate only 39.6%, i.e. commercial gas accounted for only 34×10^8 m^3. As is required by the "12th Five-Year Plan", coalbed gas production in 2015 should reach 300×10^8 m^3, including 160×10^8 m^3 produced via surface extraction, and the utilization rate should reach 100%. However, the production achieved via surface extraction in 2012 was far lower than the goal that was set for that same year. What is even more worth noting is that utilization was only 52×10^8 m^3 and the utilization rate a mere 41.6%, which was an actual reduction of 4.6% of the utilization rate in 2011 [7]. According to the statistical results for the first quarter of 2013, extraction and utilization goals were achieved in only seven provinces. All major coal producing provinces such as Shanxi, Henan, Gansu and Shandong failed to meet their targets. In particular, Hunan and Yunnan achieved only 15% and 6.5% of their goals, respectively. Even more startling, the utilization rate in Jiangsu and Xinjiang was zero. Due to insufficient fundamental researches and the defects in drilling, completion and reservoir reconstruction techniques, both the ratio of drilled wells producing gas and the ratio of drilled wells providing industrial flows are significantly lower than the expected levels, resulting in widespread low profitability. For this reason, PetroChina Company Limited -one of the country's major producers-was compelled to reduce the number of launched wells at the beginning of 2013 by 1000 (when compared to the original plan), thus making the overall production prospects even less optimistic. If the 2011 and 2012 utilized (commodity) quantities cited previously are indeed reliable, then, as was calculated by the author (and assuming that the annual growth rate of commodity coalbed gas over these two years is 23.7) the commodity quantity in 2015 should reach 100×10^8 m^3. However, if the difficulty in increasing the actual utilization rate is taken into consideration and the gas produced via mine exhaustion is converted into ordinary (standard) natural gas (as mentioned below) based on its actual alkane content, then setting the 2013 actual coalbed gas supply at 15×10^8 m^3 and predicting the 2015 actual supply to be 40×10^8 m^3should be appropriate. Based on the two figures above, the average annual growth rate of the commodity quantity of coalbed gas during these two years will reach 63.3%.

In addition, the "12th Five-Year Plan" requires the newly added proved initial coalbed gas in place to be 1×10^{12} m^3, which is nearly 3.66 times that of the 2010 cumulative proved reserves of 2734×10^8 m^{3}as stated in the "National Oil and Gas Mineral Reserves Bulletin" and is 3.71 times that of the newly added reserve of 2696×10^8 m^3 of 2010–2012. However, as far as the above mentioned failure to achieve the stipulated goals over a prolonged period of time is concerned, reaching the goals of newly added proved reserves and coalbed gas commodity quantity in just two years as is required in the "12th Five-Year" Plan will be extremely difficult. When it comes to coalbed gas reserves in China, what is most important is not the increment itself, but the need to first establish a standardized reserves calculation, declaration, approval and management system.

1.3.3. Coal-made gas

Based on its relative abundance of coal resources, China has continuously conducted exploration and carried out experiments to advance its coal chemical industry, use coal as an alternative to oil and gas, and attempt clean coal utilization. China's coal-made gas capability has become relatively mature. The 40×10^8 m^3/year coal-made gas production capacity facilities already built in Hexigten Banner will, once starting production after its supporting pipelines are completed, will be able to readily supply gas to Beijing by 2014; in addition, the coal-made gas pipeline from Fuxin to Shenyang (Beiqing) was opened in September 2013, providing an annual gas production (transportation) capacity of 10×10^8 m^3. These two pipelines are expected to reach a designed throughout of 50×10^8 m^3 by 2015. Moreover, the central government has approved project proposals for building coal-made gas plants and special West-East transportation pipelines at individual coal fields in Yining and east Junggar, in the Xinjiang Autonomous Region. However, supporting facilities and mass production of the entire production and transportation system will not be launched until the mid or later stage of the "13th Five-Year Plan".

It should be noted that China has a long history of producing urban coal-made gas. During recent years, aggressive advances have been made in the utilization of coke oven gas and the extension of its industrial chain. The commodity supply of these two types of coal-made gas in 2015 can be estimated as 5×10^8 m^3. Therefore, the total commodity quantity of coal-made gas nationwide in 2015 can be expected to reach 55×10^8 m^3.

Currently, there are only a few biomass gas (marsh gas) power generation pilot projects in China. However, statistical data related to its commodity quantity is insufficient. Based on the current estimates, biomass gas mass production can not start until the "13th Five-Year Plan" period.

In conclusion, it is predicted that the commodity quantity of fuel gas (including conventional natural gas, unconventional natural gas and coal-made gas) in China will be 1307×10^8 m^3 in 2015 – roughly calculated as 1310×10^8 m^3. This can be regarded as the total anticipated supply of domestic fuel gas in that year.

2. Change in consumption and export of fuel gas in China over recent periods

2.1. Consumption of natural gas

The comparison of data about natural gas output and consumption as is published by National Bureau of Statistics of China in past years reveals that: in and before 2006, natural gas output was higher than consumption and the difference was growing. For example, the difference was 2.1×10^8 m^3 in 1995 and 27.4×10^8 m^3 in 2006. There is no actual data to explain whether the difference partly reflects the self-utilization and loss during oil/gas production and transportation; after 2006, however, the difference between consumption and output grew rapidly. For example, the difference was 13.8×10^8 m^3 in 2007 and 378.6×10^8 m^3 in 2012. The latter reflects that the import volume of natural gas has grown continuously.

The results of study made by the author on the basis of the data from National Bureau of Statistics reveal that: during 1995–2000, 2000–2005 and 2005–2011, the annual growth rate of natural gas consumption in China was 6.67%, 13.80% and 18.69% respectively, and reached 25.61% in 2007 and 21.50% in 2011, showing a trend of rapid increase. After 2011, however, the situation somewhat changed. In 2012, the annual growth rate was reduced sharply to 10.60%. The actual consumption in the first half of 2013 was 820×10^8 m^3, a year-on-year increase of 14.6%; assuming that the annual consumption will increase at the rate of 14.8%, the annual consumption will be 1660×10^8 m^3. The author believes that, this change reflects the fact that the annual growth rate curve has reached its inflection point, and it is not very likely that the five-year average annual growth rate can exceed 20% in the future.

The market situation over recent years is that the abnormal low gas price has resulted in losses to gas importers and producers, and this has become one of the reasons for low investment made into the higher-cost development of unconventional gas (especially for the early stage of exploration and development). Without other conditions, the constraint by high gas price on consumers will become increasingly obvious. Under the guideline that the upper limit of inflation rate may not be exceeded, however, the increase of gas price will be constrained by many factors. If the gas price can't reflect the supply-demand relationship in market and comprehensive costs for a long term, then the situation that the growth of gas production and consumption is constrained by low gas price will not be changed in a short term. In such a dilemma, the author set the annual growth rate of natural gas consumption in China at 18% in 2014 and 2015 and 16% during the 13th Five-year Plan period, then the consumption in 2015 and 2020 will be 2310×10^8 m^3 and 4850×10^8 m^3 respectively (Table 3). As any prediction has preconditions, if the reform is properly implemented and the price is normalized, then the annual growth rate of natural gas consumption may be higher; otherwise, the annual growth rate may be lower.

Table 3
Changes in natural gas consumption in China during 2011–2020.

Consumption in 2011/10^8 m^3	Consumption in 2012/10^8 m^3	Annual growth rate	Consumption in 2013/10^8 m^3	Annual growth rate	Consumption in 2015/10^8 m^3	Annual growth rate	Consumption in 2020/10^8 m^3	Annual growth rate
1307	1446	10.60%	1660	14.8%	2310	18%	4850	16%

Note: The original data of 2011 and 2012 was sourced from the National Bureau of Statistics of China, while the data of 2013, 2015 and 2020 were predicted by the author. (Refer to the main body of this paper for details).

2.2. Import volume of natural gas

The import of natural gas with statistical data in China commenced in 2006, but the net import volume of natural gas was still very low until 2008. In 2009, the annual growth rate of natural gas output was sharply reduced to 6.19%, which resulted in the inflection point for rapid growth of net import volume and a 4.9% dependency on natural gas imports. Owing to the continuous development of the above trend, the import volume of natural gas increased rapidly during 2010–2012, and the dependency on natural gas imports rose up to 26.2% in 2012. In 2013, owing to the adjustment of gas price, the growth of natural gas imports in the first half of the year slowed down, but judged from the trend, the import volume will increase again in the second half. Therefore, it is predicted that the import volume of natural gas in 2013 will reach 550×10^8 m^3, and the dependency on natural gas imports will reach 33.1% (Table 4). In 2012 and 2013, the annual growth rate of natural gas imports in China was 29.94% and 34.80% respectively, and according to the above prediction on consumption and supply of natural gas in China in 2015, the difference will be 1000×10^8 m^3, which should be made up by imported gas. Table 4 also reveals that, the export volume of natural gas of China has been on the decline since 2010 and may be ignored against the rapid increase in imports. Therefore, in the prediction for 2015 and subsequent years, the import volume may be deemed as net import volume.

According to the data obtained by Tian Chunrong, China imported 399×10^8 m^3 (which is different from the figure given in Table 4, but still falls in the reasonable difference caused by the variation in statistical ranges) of natural gas in 2012, including 199×10^8 m^3 of piped gas and 200×10^8 m^3 of liquefied natural gas (LNG) from the Central Asia [8] (about 1470×10^4 t). The six LNG receiving terminals which would, as planned, be put into operation in the year, were completed in autumn in 2012, with a designed annual receiving capacity of 1880×10^4 t (about 260×10^8 m^3). After the running-in period, they can fully achieve the designed annual import volume in 2015. The Myanmar–China oil and gas pipeline was basically completed in 2013 and can also achieve the designed import volume of 120×10^8 m^3 in 2015. According to the agreement reached between China and Turkmenistan in September 2013, the construction of China–Central Asia natural gas pipeline C will be completed and great progress will be made in gas field development by 2013, and it will be possible to supply 300×10^8–350×10^8 m^3 of natural gas to China in 2015. Therefore, the LNG receiving terminals which have been put into operation and the piped gas importable will constitute an import capacity of 680×10^8–730×10^8 m^3. There will still be a difference of 270×10^8–320×10^8 m^3 between the import capacity and the above demand on imported gas (1000×10^8 m^3) in the year mentioned. Obviously, in order to meet the expected consumption in 2015, it is necessary to increase the import volume by taking new measures. Thus, among the seven LNG receiving terminals which will, as is planned, be completed in 2015, some should be completed and have the ability to receive and transport gas at the end of 2014, so as to increase the annual import volume of LNG by 150×10^8–200×10^8 m^3. In addition, the volume of natural gas imported from Central Asia should be increased until the annual import volume reaches 450×10^8–500×10^8 m^3. Therefore, it is necessary to immediately make arrangement and implement the relevant work.

It is a matter of concern that the gas shortage which once occurred in winter in China has recurred and worsened over recent years. This is not only related to the gap in annual supply, but also the absence of supporting measures such as peak modulation [9]. In 2011, the gas shortage only occurred in a few areas in Shandong and Hunan; in 2012, it spread to some areas in more than 10 provinces including Beijing, Hubei, Zhejiang, Jiangsu and Inner Mongolia. The prolonged smog has forced the government of many cities (especially those in North China) to make arrangement for coal-to-gas work in advance, so that the limited gas supply occurred in some places even during the off season in the year. It is

Table 4
Import volume of natural gas and dependency on imports of China during 2005–2013.

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013
Import volume/10^8 m^3	0	10	40	46	76	165	314	408	550
Export volume/10^8 m^3	30	29	26	32	32	40	32	29	20
Net import volume/10^8 m^3	−30	−19	14	12	44	125	282	379	530
Dependency on imports		−3.5%	12.0%	1.7%	4.9%	11.6%	22.0%	26.2%	31.5%

Note: The original data was sourced from the National Bureau of Statistics and the General Administration of Customs, but the data of 2013 were calculated and estimated by the author on the basis of the data obtained in the first half of the year.

expected that gas shortage will become more serious in this winter and next spring, the influence scope will be larger (maybe covering the upstream and midstream of West-to-East Gas Transmission Line), and some LNG enterprises may be involved in limited or disconnected gas supply. In the future, with the accelerated urbanization process and increased environmental pressure, the supply of fuel gas will be under higher pressure. The historical experience once again reminds us that, we should not only pay attention to the supply and import volume of fuel gas, but also attach importance to the construction of auxiliary facilities at midstream and downstream and especially the corresponding peak modulation capacity.

3. Suggestions concerning target research on nature gas of China during the 13th Five-year Plan period

China's economy is in the middle of transformation and structural adjustment, and the economic system reform is entering into the "deep-water area". At this moment, it is imperative and necessary to summarize the past experience (especially the experience and lessons of recent years) and carry out the energy planning research for the 13th Five-year Plan period in advance. On the basis of the discussion hereunder, some pieces of advice are hereby brought forth with respect to the basic research in natural-gas-related planning, in the hope to attract better ideas.

3.1. To improve the statistics and management of natural gas

With respect to conventional oil and gas, China has formed the statistical and management systems for upstream, midstream and downstream, and most of them are in line with the international practices. This has laid a foundation for the achievement of correct understanding. As for unconventional oil and gas, however, there exist many problems, and even the basic data are not clear, so no research can be carried out!

3.1.1. To improve the statistics and research of commodity gas

Owing to the planned economic system, the output has been confused with the actual supply in China for long time, and there is not any concept of commodity rate. This is the aspect which has not been in line with the international practice. The wellhead output counted by every production company is the basis for all statistics, and on this basis the balance sheet among accumulative proven geologic reserves, recoverable reserves, annual output, accumulative output and remaining recoverable reserves is formed. As for the gas produced in well, a portion is separated as condensate oil (which has been included in oil for the purpose of statistics) at the wellhead, a portion is used as power and fuel in oil/gas field, a large portion is refilled underground for increased production of oil (this is a popular practice in the Middle East where most of the gas is associated gas and more importance is attached to oil production, and is more and more adopted in oil producing areas in China), and a portion is flared. Even the gas which has entered into the outgoing pipeline station may be subject to loss in the course of transportation. For example, it may be used as fuel in booster station. The gas may also be subject to such loss in the course of production, transportation and regasification of LNG. Except for the natural gas used and lost in the course of production and sales, the ratio between volume of natural gas which can be supplied as commodity to consumption markets and wellhead output is called as commodity rate. The value of commodity rate may vary greatly under different conditions. At the early stage of exploration and development of natural gas, the loss rate may be very high, so the commodity rate may be lower. According to the statistical data of France International Natural Gas Information Center (CEDIGAZ), the commodity rate of global natural gas output has fluctuated between 80% and 85% since the end of last century [1]. For example, in 2006, the natural gas refilled, flared and otherwise lost accounted for 11.0%, 3.3% and 5.7% of the total output respectively, and the commodity rate was only 80%. What should also be noted is that if subsidy is granted to some low-gas-production wells (including the unconventional gas production at an early stage), such subsidy should also be included as actually-sold commodity, so it is very unreasonable to require subsidy for natural gas internally used and flared.

Obviously, in the course of improving the market economy, it is necessary to take the volume of commodity gas as the equilibrium condition for research on the relationship between consumption and import volume. It is advised to add this ignored link in subsequent planning and prediction. However, it is still necessary to carefully study the issues such as how the commodity rate can be calculated in line with the reality of China and whether it is appropriate to adopt the commodity rate of 90% in the prediction of volume of commodity gas during the later stage of the 12th Five-year Plan period and the 13th Five-year Plan period.

3.1.2. To improve the statistics and management of coalbed gas

The discussion above reveals that, even if only the blocks which are registered by the State are considered, the exploration and development of coalbed gas has not been brought under the full-process regulation by competent authorities. With respect to reserves, all the industrial insiders know that, every company's proven conventional oil/gas reserves which have been preliminarily approved will be greatly reduced in the course of review by legally-designated review authority (National Commission of Mineral Reserves). In addition, the current reserve specifications also specifies that, the reverse shall be re-calculated at the specified interval after the investment in development, and it is more important to unconventional oil/gas, of which the proven reserve and recovery ratio have to be determined on the basis of closely-located production wells and single output change curve. In order to lay the foundation for scientific management, summarize the experience and further improve the specifications and standards for coalbed gas in light of the actual situation of China, it is necessary to adhere to the strict reserve management system.

The coalbed gas from the two major sources (surface extraction and mine drainage) is different from each other in the aspects of development and utilization. With respect to composition, the coalbed gas obtained through surface extraction is almost 100% composed of pure methane, while the coalbed gas obtained through mine drainage is mixed with a lot of air, and sometimes the methane concentration is low or very low. Internationally, the volume is calculated on the basis of standard cubic meter (Nm^3) in the natural gas research, which requires that the gas of different hydrocarbon content should be converted in accordance with the relevant standard. It is very unreasonable and even misleading to get the output of coalbed gas by simply adding the output from surface extraction and mine drainage, and to get the volume of coalbed gas utilized by simply adding the utilized volume of coalbed gas from surface extraction and mine drainage. The utilization of coalbed gas from surface extraction is similar to that of common natural gas, but the current utilization ratio is very low, and it is very difficult to utilize the coalbed gas from mine drainage. Obviously, the commodity rate should be emphasized for the latter. The conditions of coal mines decide that no electricity shortage or coal shortage exists in coal mines, and the coalbed gas is mainly used for power generation. Though China has developed many kinds of generating equipment which uses the coalbed gas of low or extremely low concentration, the coal mines are enthusiastic about making investment in setting up another coalbed-gas-based power generation and utilization system, and the connection to an external power grid is difficult and costly (the subsidization policies can't be fully implemented). As for the whole coal industry wherein the low coal price will prevail for a long time, especially those small- and medium-sized coal mines, it will be very difficult to change the present status and raise the utilization ratio of coalbed gas. Therefore, this should be fully considered, and good countermeasures should be formulated.

Another concern is the management system for coalbed gas. Document No. 93 issued by the State Council in September 2013, namely the *Opinions on further Accelerating Extraction and Utilization of Coalbed Gas* (*Gas of Coal Mine*) contains more provisions for promoting the development of coalbed gas than the previously-issued relevant documents, and this should be fully recognized. However, the provisions in such documents relating to many key issues which affect the development of coalbed gas are still given as princes, directions or frameworks, and there is no clear or practical provisions. For example, only very few exploration and development blocks for coalbed gas are approved, and no specific measures are given for the serious contradiction between such blocks and coal mines or petroleum enterprises. There is also no clear provisions on the issue of how coalbed gas can enter into the existing gas transmission pipelines, and no powerful and feasible measures are given for the improvement of utilization ratio of coalbed gas. After the reform has entered into the "deep-water area", if the fundamental obstacles for the development of coalbed gas can't be thoroughly eliminated through a system reform, it will be difficult to change the situation that the development has been slow for a long time [7].

3.1.3. To establish the regulation system for shale gas

China has only taken a tentative step towards the development of shale gas. With respect to shale gas as a newly-established separate mineral type, many rules, regulations and administrative measures may be formulated by borrowing ideas from those for conventional gas and the United States' experience in shale gas, more innovation is also required. Firstly, it is necessary to complete the formulation of specifications and standards covering geologic exploration, reserve approval and development operations, and this work can't be achieved at a single leap. At present, it is necessary to firstly prepare the urgently-required drafts, and then form the specifications and regulations (covering management system and environmental monitoring) which can be used as a working guideline and a regulation basis and include them into the national or industrial standard system within several years through a round of actual operation. This work has commenced. For example, the draft specifications for soliciting opinions have been prepared for shale gas reserves, and the preliminary feedback indicates that it should be supplemented and improved to a relatively great extent. In particular, the requirements on shale gas of different types (such as marine, terrestrial, and interactive marine & terrestrial coal measure) should be different from those on shale gas associated with conventional gas, tight gas and coalbed gas. Among them, some types are not covered by the specifications and standards of the United States, and for some types, the clear specifications and standards for conventional oil/gas are also absent.

By the way, this type of work is also incomplete for coalbed gas and tight gas. The above mentioned situation that the coalbed gas is narrowly covered by the national reserve notification is an example. The reserve and output of tight gas as a separate type of unconventional gas is counted separately in countries such as the United States, but is confused with those of conventional gas in China. In particular, the specification system for the use of horizontal wells and fracturing technologies are absent (including the specifications for tight gas reserve), which is also very unfavorable for a sustainable development of tight oil/gas.

3.2. To face up to the difficulties encountered in development, and to avoid a high target

Through a review on the development of natural gas industry in China over recent years, many researchers have noticed a phenomenon: a very high expectation was imposed on natural gas growth and strong pressure caused by a high target, but some targets were not achieved, and the achievement of some targets was even delayed for one period (about 5 years). This indicates that, our understanding of the situation and development law of natural gas and energy in China is not profound enough. In other words, the practical, innovative and predictive basic research should be strengthened.

The author believes that when it comes to analyzing the production of natural gas in the near future, it is necessary to note the fact that, the annual growth rate of natural gas output as is published by China has reduced from two-digit

percentage to one-digit percentage. This is constrained by the following factors.

1) The exploration and development technologies for conventional gas have become increasingly mature, the production of some old gas fields has been stabilized or even reduced, and this situation also occurred to the main gas fields which were put into operation not long ago. For example, the annual natural gas output of Jingbian Gas Field, the largest conventional gas field in the Ordos Basin, was 46.72×10^8 m^3 in 2011 but reduced to 43.98×10^8 m^3 in 2012; the largest Datianchi Gas Field of PetroChina Southwest Oil and Gasfield Company in the Sichuan Basin was 33.46×10^8 m^3 in 2010 but reduced to 27.73×10^8 m^3 in 2012.
2) Conventional natural gas is composed of gas-bed gas and associated gas (dissolved gas), the latter has a lower commodity rate, its wellhead output fluctuates along with the oil output, and has reduced in old oil areas in East China [10].
3) The proportion of unconventional tight gas output in total natural gas output in China has increased continuously, and this situation is more obvious in the Ordos Basin and the Sichuan Basin (main producing areas of gas-bed gas in China). The affecting factors for production increase and stabilization are different from those for conventional gas.
4) The growth of output of other unconventional gas (coalbed gas and shale gas) has to be realized through a gradually-accelerated process, for this purpose, the special geologic conditions in China should be fully considered and the unique supporting technology system should be formed in advance [11].
5) The base of natural gas output has increased rapidly, so the annual growth rate may still reduce even if the annual increment grows.

The analysis above reveals that maybe the value (8%) of annual growth rate adopted by the author when predicting the growth of natural gas output in China during the 13th Five-year Plan period is not a low value.

3.3. The progress in reforms is the key factor which constrains the development of oil and gas industry

The above analysis only covers the objective situations of some resources which affect the development of oil and gas industry. If analyzed on the basis of the actual situations of China, the more important factor which affects the development of oil and gas industry is the social environment, namely the problems existing in economic regime and the incomplete development of market economy. This is embodied especially in coalbed gas and shale gas [10,12].

Having a lawful exploration & development block is the premise for upstream oil/gas operation. According to the current regulations, the power to manage conventional oil/gas, tight oil/gas and coalbed gas blocks lies with the Ministry of Land and Resources, and only those large State-owned oil companies are admitted to such business. The relevant regulations also require that the area of block will be reduced or the block will be canceled in case the specified workload is not finished and the relevant report and geologic data are not submitted within the specified time limit, but in fact, such provisions are not earnestly implemented. As a result, almost all favorable blocks where such oil/gas exploration can be carried out are monopolized by a few enterprises, and the block admission/withdrawal mechanism became a pool of stagnant water. As for coalbed gas, there are few registered blocks, and there is also the contradiction that some blocks are overlapped with coal mine blocks. As for shale gas, a new mineral type, though the block admission conditions are widened, the blocks available are only limited to those corners and edges of sedimentary basins which have not been registered for conventional oil/gas and coalbed gas. Most of such corners and edges have unfavorable geologic conditions and poor transportation conditions, which increases the difficulty for those companies which have just entered into the oil and gas industry, and is not favorable for the development of shale oil/gas. The monopoly on blocks and upstream operations is only an example, and there are also problems relating to the administrative monopoly and management system in midstream and downstream [13,14].

Whether the oil/gas reform can be implemented smoothly in "deep-water area" has become the key factor which decides whether the oil and gas industry in China can develop sustainably. We hope that a breakthrough can be made by this round of reform in the late 12th Five-year Plan period, so as to ensure that the reform can be generally generalized throughout the country in the middle 13th Five-year Plan period and the bonus from reform can be obtained in the late 13th Five-year Plan period. Since there is no clear judgment on the progress of monopoly breaking and reform intensifying, it is difficult to answer the questions such as "How can a vital oil/gas market advancing with the development of both State-owned and private enterprises be formed" and "when can some unfavorable trends be changed obviously". Therefore, the author has not predicted the supply, consumption and import volume of fuel gas in China in 2020.

From this viewpoint, the values predicted in this paper are also quite uncertain, and they are only the possible values under the precondition that the reform is implemented smoothly. If no actual effect can be obtained through the implementation of system reforms, various links of natural gas industry can't match with each other perfectly, so the predict values of output, import volume and consumption of natural gas in China will also be reduced. Otherwise, the above values may be higher.

References

[1] Zhang Kang, Zhang Wenchang. Issues in statistical work and forecast of natural gas resources in China. Nat Gas Ind 2012;32(1):6–11.
[2] Zhang Kang. Adjusting the direction of natural gas exploration to enhance continuous development. Nat Gas Geosci 2003;14(5):327–36.
[3] Zhang Kang. Live cycle and strategic replacement of oil and gas field in China. Beijing: Geological Publishing House; 2001.
[4] Zhang Dawei. The current state in China of shale gas exploration and development, and external cooperation. Int Pet Econ 2013;21(7):47–52.

[5] Zhang Kang. From tight oil and gas to shale oil and gas − an approach to developing unconventional oil and gas in China. Int Pet Econ 2012;20(3):9−15.
[6] Liao Yongyuan, Luo Dongkun, Li Wandi. Development strategy analysis of China's CBM. Acta Pet Sin 2012;33(6):1098−101.
[7] Zhang Kang. Lessons for shale oil & gas development from that of tight oil & gas and coalbed methane gas in China. Nat Gas Ind 2013;33(4):18−25.
[8] Tian Chunrong. China's oil and gas imports and exports. Int Pet Econ 2013;21(3):44−55.
[9] Zhang Kang. Rational reflection on the gas shortage panic. Int Pet Econ 2010;18(1):40−4.
[10] Zhang Kang. Distribution characteristics and enrichment controlling factors of China's dissolved gas. Nat Gas Geosci 2009;20(5):641−50.
[11] Lu Xuemei, Zhang Kang. The analysis of main factors influencing China's shale oil-gas development. Petroleum Petrochem Today 2012;20(8):13−7.
[12] Zhang Kang. Development of shale gas rely on reform only. Caijing Mag 2013;(12):142.
[13] Zhang Kang. Strategic replacement situation and outlook of China oil-gas production area. Petroleum Explor Dev 2012;39(5):513−23.
[14] Zhang Kang, Zhang Lulu. Speed up production of oil available types of oil and gas. Sino-Global Energy 2013;18(9):1−6.